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DEPARTMENT OF
CIVIL ENGINEERING

Lecture Notes
on
23CE703 - Prestressed Concrete

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UNIT V

Composite Sections

A composite section in context of prestressed concrete members refers to a section with a precast member and cast-in-place (CIP) concrete. There can be several types of innovative composite sections.

The advantages of composite construction are as follows.

1) Savings in form work
2) Fast-track construction
3) Easy to connect the members and achieve continuity.

The prestressing of composite sections can be done in stages. The precast member can be first pre-tensioned or post-tensioned at the casting site. After the cast-in-place (cast-in-situ) concrete achieves strength, the section is further post-tensioned.
The grades of concrete for the precast member and the cast-in-place portion may be different. In such a case, a transformed section is used to analyse the composite section.

5.1 Analysis of Composite Sections

The analysis of a composite section depends upon the type of composite section, the stages of prestressing, the type of construction and the loads. The type of construction refers to whether the precast member is **propped** or **unpropped** during the casting of the CIP portion. If the precast member is supported by props along its length during the casting, it is considered to be propped. Else, if the precast member is supported only at the ends during the casting, it is considered to be unpropped.

The following diagrams are for a composite section with precast web and cast-in-place flange. The web is prestressed before the flange is cast. At transfer and after casting of the flange (before the section behaves like a composite section).

From the analysis for ultimate strength, the ultimate moment capacity is calculated. This is compared with the demand under factored loads. The analysis at ultimate is simplified by the following assumptions.

1) The small strain discontinuity at the interface of the precast and CIP portions is ignored.

2) The stress discontinuity at the interface is also ignored.

3) If the CIP portion is of low grade concrete, the weaker CIP concrete is used for calculating the stress block.

5.2 Design of Composite Sections

The design is based on satisfying the allowable stresses under service loads and at transfer. The section is then analysed for ultimate loads to satisfy the limit state of collapse. The member is also checked to satisfy the criteria of limit states of serviceability, such as deflection and crack width (for Type 3 members only). Before the calculation of the initial prestressing force (P_0) and the eccentricity of the CGS (e) at the critical section, the type of composite section and the stages of prestressing need to be decided. Subsequently, a trial and error procedure is adopted for the design.

The following steps explain the design of a composite section with precast web and cast-in-place flange. The precast web is prestressed before the casting of the flange. The member is considered to be Type 1 member.

Step 1. Compute e.

With a trial section of the web, the CGS can be located at the maximum eccentricity (e_{max}). The maximum eccentricity is calculated based on zero stress at the top of the precast web. This gives an economical solution. The following stress profile is used to determine e_{max}.

Step 2. Compute equivalent moment for the precast web. A moment acting on the composite section is transformed to an equivalent moment for the precast web. This is done to compute the stresses in the precast web in terms of the properties of the precast web itself and not of the composite section.

Step 3. Compute P_e

Let M_P be the moment acting on the precast web prior to the section behaving like a composite section. After M_c is applied on the composite section, the total moment for the precast web is $M_P + m_b M_c$.

Step 4. Estimate P_0 as follows.

a) 90% of the initial applied prestress (P_i) for pre-tensioned members.

Equal to P_i for post-tensioned members.

Step 5. Check for the compressive stresses in the precast web.

Step 6. Check for the compressive stress in the CIP flange.

5.3 Analysis for Horizontal Shear Transfer

With increase in the load, the bottom face of the CIP portion tends to slip horizontally and move upwards with respect to the top face of the precast portion. To prevent this and to develop the composite action, shear connectors in the form of **shear friction reinforcement** are provided.

The minimum requirements of shear friction reinforcement and spacing are similar to that for shear reinforcement in the web.

Deflection

The deflection of a flexural member is calculated to satisfy a limit state of serviceability. Since a prestressed concrete member is smaller in depth than an equivalent reinforced concrete member, the deflection of a prestressed concrete member tends to be larger.

The total deflection is a resultant of the upward deflection due to prestressing force and downward deflection due to the gravity loads. Only the flexural deformation is considered and any shear deformation is neglected in the calculation of deflection. Shear deformation is included in members such as deep beams and wall type of structures.

The deflection of a member is calculated at least for two cases.

1) Short term deflection at transfer
2) Long term deflection under service loads

The short term deflection at transfer is due to the prestressing force (before long term losses) and self-weight. The effect of creep and shrinkage of concrete are not considered. The long term deflection under service loads is due to the effective prestressing force (after long term losses) and the gravity loads. The permanent components of the gravity loads are considered in the effect of creep. These components are dead load and sustained live load.

5.4 Deflection due to Gravity Loads

The methods of calculation of deflection are taught in a course on structural analysis.

It is expected that the students are familiar with the methods. The methods include the following.

1) Double integration method
2) Moment-area method

3) Conjugate beam method

Numerical solution schemes can be developed based on the above methods and executed in a computer. For members with prismatic cross-sections, common support conditions and subjected to conventional loading, the deflections are available in tables of text books on structural analysis.

5.5 Deflection due to Prestressing Force

The prestressing force causes a deflection only if the CGS is eccentric to the CGC. The deflection due to prestressing force is calculated by the load-balancing method. This method is explained in Section 3.2, Analysis of Member under Flexure (Part I). The upward thrust (represented as w_{up} for curved tendons and W_{up} for bent tendons) and the upward deflection (also called camber and represented as Δ_P) due to the prestressing forces in typical profiles of tendons are reproduced here.

Total Deflection

The total deflection is calculated for the following two cases.

1) Short term deflection at transfer
2) Long term deflection under service loads

The long term deflection under service loads is difficult to calculate because the prestressing force and creep strain influence each other. Creep of concrete is defined as the increase in deformation with time under constant load. Due to the creep of concrete, the prestress in the tendon is reduced with time. The ultimate creep strain is found to be proportional to the elastic strain. The ratio of the ultimate creep strain to the elastic strain is called the creep coefficient θ. The values of θ as per IS:1343 - 1980 are given in Section 1.6, Concrete (Part II).

5.6 Limits of Deflection

Clause 19.3.1 of IS:1343 - 1980 specifies limits of deflection such that the efficiency of the structural element and the appearance of the finishes or partitions are not adversely affected. The limits of deflection are summarised next.

1. The total deflection due to all loads, including the effects of temperature, creep and shrinkage, should not exceed span / 250.
2. The deflection after erection of partitions or application of finishes, including the effects of temperature, creep and shrinkage, should not exceed span/350 or 20 mm,

whichever is less.

3. If finishes are applied, total upward deflection due to prestressing force should not exceed span / 300.

5.7 Determination of Moment of Inertia

Type 1 and Type 2 Members

These types of members are designed to be uncracked under service loads. The gross moment of inertia (I_g) can be used to calculate the deflections.

Type 3 Members

This type of members is expected to be cracked under service loads. Strictly, the gross moment of inertia (I_g) cannot be used in the calculations. IS:1343 - 1980, Clause 22.6.2, recommends the following.

1. When the permanent load is less than or equal to 25% of the live load, the gross moment of inertia can be used.
2. When the permanent load is greater than 25% of the live load, the span-to- effective depth (L/d) ratio should be limited to bypass the calculation of deflection

If the L/d ratio of a member exceeds the limit, the gross moment of inertia can still be used if the tensile stress under service loads is within the allowable value. This recommendation is suggested because the calculation of gross moment of inertia is simpler as compared to an effective moment of inertia

5.8 Limits of Span-to-Effective Depth Ratio

The calculation of deflection can be bypassed if the span-to-effective depth (L/d) ratio is within the specified limit.

The limits of L/d ratios as per Clause 22.6.2, IS:1343 – 1980, are as follows. For L $\leq$ 10 m

For cantilever beams, $L/d \leq 7$

For simply supported beams, $L/d \leq 20$

For continuous beams, $L/d \leq 26$

For L > 10 m

For simply supported beams, $L/d \leq (20 \times 10/L)$

For continuous beams, $L/d \leq (26 \times 10/L)$ Here, L

is in metres. Deflection calculations are necessary for c